Cloud Management Optimization – Issues and Developments

Isaac Odun-Ayo, *Member, IAENG*, and Frank Agono

Abstract — **Cloud computing is the current technology paradigm that portends the greatest potentials to revolutionize the way IT activities are conducted. Cloud computing influences most known areas of activities in human endeavour. The cloud provides easy to use applications that can be accessed online at any place and time. Cloud computing also allows organisations and enterprises to create and deploy own applications. In addition, the cloud offers extendable storage facilities, inclusive of processing capabilities. The cloud utilizes various data centres with physical machines or servers for storage and computing purposes. These data centres consume a high amount of energy. The electricity utilization is high and it continues to increase. The servers and cooling machines consume a lot of energy, hence the need to manage this in an optimal way. The study was executed by means of review of some literature available on cloud management optimisation. This study examines issues and developments of cloud management optimisation and also present a recommendation for future research. The result only 25% of the core papers examined discussed the issue of cloud virtualization as it relates to cloud management optimisation. This outcome will offer insight for further work in cloud management optimisation.**

Index Terms–**Cloud Computing, Virtualization, Optimization**

I. INTRODUCTION

"CLOUD computing represents a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [1]. Cloud computing is dynamically evolving, yet making significant impact in diverse areas of life. More enterprises are migrating to the cloud and new technological developments are taking place. Cloud computing offers several benefits to organizations, enterprises and small businesses alike. Most enterprises can reduce spending by leveraging on the infrastructure available on the cloud. Cloud services can be categorized in three primary ways. Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). SaaS offers the cloud user customized applications for use. Cloud service providers (CSPs) ensures the availability of applications over the Internet for use by cloud consumers. Cloud consumers need not bother about installing software or even software licences. In PaaS, the CSP provides a platform for each user to develop and deploy applications. Each user exercises control over his applications and some resources, while the CSP maintains total control over the platform. In IaaS, the CSP provides the cloud user with network, storage, memory and compute resources at a fee. The core process here is virtualization. The user has access to the CSP's infrastructure and is able to utilize all the software resources associated with the resource usage. Cloud computing also offers four deployment types: the private, public, community and hybrid clouds. The private cloud is owned entirely by an organization, usually accessed by internal staff only and making it more secure. Infrastructure can be on-premise or off–premise. Public clouds have infrastructure on a much larger scale usually owned by major CSPs. Public cloud offers different kind of services to users on a metered basis. However, they are considered less secure. Community cloud is usually owned by several organizations agreeing to use the same infrastructure based on a shared common interest. Community clouds are usually either managed by the community itself or outsourced to a third party company. Hybrid clouds form a combination of community, private and the public cloud environments. They operate as unique entities, sharing the same infrastructure, but managed as a single unit. Hybrid clouds allow organizations retain core activities in the private cloud, while less essential activities are migrated to the public cloud.

Cloud management usually refers to software applications and platforms useful for monitoring and managing operations, services and data in the cloud [2]. Cloud management tools and technologies ensure the optimal performance of cloud services and resources. Cloud management involves task such as performance monitoring, security and compliance issues [2]. Cloud optimization refers to making more efficient and effective use of computing resources and other infrastructure on the cloud. Excluding the cost and responsibilities of its users, cloud computing allows businesses to begin on a smaller scale and thrive gradually thus ensuring optimal development. Flexible pricing models allows cloud users to predict the cost of usage beforehand. The processor, storage and network resources utilises the pay-per-use payment model. Users get access to resources, uses the resources for as long as they want and then relinquish them afterwards [2]. Projections have revealed that by ensuring up-to-date multiplexing of the resources and usage statistics of large organisations, cloud computing amounts to about 5-7 percentage decrease in the cost of electricity, network

Manuscript received April 05, 2018; revised May 10, 2018. This work was supported in part by the Covenant University through the Centre for Research, Innovation and Discovery (CUCRID).

I. Odun-Ayo is with the Department of Computer and Information Sciences, Covenant University, Ota, Ogun State Nigeria. (+2348028829456; Isaac.odun-ayo@covenantuniversity.edu.ng)

F. Agono is with the Department of Computer and Information Sciences, Covenant University, Ota, Ogun State, Nigeria. (+2348123688797; email: frank.agono@stu.cu.edu.ng)

bandwidth, operations, software and hardware requirements [3]. Cloud computing also provides energy–efficiency through elimination of redundancies and efficient resource management by CSP.

The aim of this paper is to discuss, cloud management and optimization. The paper will examine what management and optimization entails. It also highlights trends in the industry. The remaining part of the paper is as follows. Section 2 deals with related work. Section 3 examines the concept of cloud management and optimization. Section 4 of the paper presents current trends in this field. Section 5 concludes the paper and recommends further research.

II. RELATED WORK

In [4], Autonomic Management of Cloud Service Centres with Availability Guarantees is presented. In the cloud environment, changes occur beyond the control of the cloud service providers. This is resolved by autonomic solutions in terms of performance and energy trade-offs. The paper focuses on solution in terms of availability. In [3], A Business-Driven Cloud Optimization Architecture is proposed. Several issues in optimization were discussed and framework for addressing the challenges were examined. The framework enhances different optimization concepts. In [5], Cost optimization of virtual infrastructure in dynamic multi-cloud scenarios is proposed. Pricing schemes and other benefits makes the cloud attractive. Cloud brokers have also made it easy to decide on suitable providers. The paper employs brokerage to ensure optimum deployment of servers. In [6], Energy Efficient Resource Management in Virtualized Cloud Data Centres is presented. The paper proposed an efficient energy utilization in cloud data centres. The outcome shows that energy is saved without jeopardising QoS. In [7], Application Centric Cloud Management is proposed. The infrastructure approach is often used in cloud optimization. The paper proposes an application centred approach for optimization and for ensuring that the user application can utilize resources from different providers. In [8], Efficient Resource Management for Cloud Computing Environments is presented. The focus is on the optimal utilization of resources in data centres. Various techniques were presented to improve overall performance. In [9], the concept of revenue management is proposed to allow optimum benefit in the provision of cloud services. In [10], IaaS Cloud Architecture: From Virtualized Datacenters to Federated Cloud Infrastructures is presented. The architecture presented discusses the relevance of the cloud operating system. It is expected to manage physical and virtual resources and ensure scalability among cloud providers. In [11], a novel agent-based autonomous and service composition framework for cost optimization of resource provisioning in cloud computing is proposed. The main aim is to reduce the cost of virtual machine utilization while ensuring customer satisfaction. A framework is proposed for request processing and provision of resources.

In [12], Risk perception and risk management in cloud computing: Results from a case study of Swiss companies is proposed. The paper explores the risks involved in cloud utilization in present times. An analysis was carried out on Swiss companies on the cloud and the result was that of risk awareness before adoption. In [13], Resource usage optimization in Mobile Cloud Computing is proposed. The focus is on resource demand in mobile cloud computing. A framework was proposed and evaluated with good results in terms of resource demand. In [14], Revenue management for Cloud computing providers: Decision models for service admission control under non-probabilistic uncertainty is presented. The focus is to ensure that services are available to the consumers while at the same time cloud providers maximise profit.

III. CLOUD MANAGEMENT AND OPTIMIZATION

A. Goals of Management and Optimization

Cloud management means exercising administrative rights over cloud architectures [15]. A well-actualised management plan enables cloud users to exercise control over the scalable and dynamic environment on the cloud. The following are some of the goals of management and optimization [15].

1) *Self – Service Capability:* The introduction of cloud management, grant users the ability for self-service. Thus, eliminating the conventional process involved in the provisioning of IT resources. Users have the ability to access the several available cloud types, users can monitor current cloud processes, establish new processes, monitor usage and adjust cost of resource allocation. Using the reporting capabilities, users can track budgetary allocations and make adjustments where necessary so as to reduce operating costs.

2) *Workflow Automation:* Cloud management enables the automation of workflow. Automation enables organisations transform their business strategies and policies into actions and steps required to create and handle cloud instances with minimal human assistance or interference. Asides functioning in creating, placing and adjusting of intensive cloud processes, automating organisational workflow assists organisations attain desired compliance and report requirements. For instance, cloud management tools have the feature that sends information to a manager in the event of an employee trying to transmit the files and activities of a private cloud to a public cloud, which can lead to violation of the company’s security and compliance regulations or policies thus attracting potential sanctions from regulatory bodies.

3) *Analysis of workload:* Cloud management allows the analysis of ongoing user experiences and cloud workload. An organisation using a private cloud can ascertain the functionality of its cloud infrastructure and offer basic activities such as balancing organisational workload and capacity planning. In public cloud environments, server downtime measurements help enforce adherence to the public cloud provider service level agreement. By employing the use of measurements criteria, companies get to choose the period it desires to use cloud service providers or when it is necessary to migrate the workload from public to private clouds. Public cloud service providers deploy complex tools to match the requirements of the services provided.

B. Strategies for Cloud Optimization

Cloud management and optimization is about improving efficiency in the utilization of infrastructure. The variety of services cloud computing offers continually represents an integral part of an organisation's Information Technology infrastructure, hence management teams in organizations realise the need for cloud optimization [16]. Organisations have found that it is more satisfactory not only to simply implement cloud services, but the need for proper and close monitoring and evaluation of resources to ensure optimal performance and productivity. Discussed below are some strategies for cloud optimization [16]:

1) *Governance Strategy:* Cloud governance is closely related to cloud optimization. Cloud governance strategy determines the methodology by which an organisation evaluates and maintains its cloud solution using already stated guidelines. Cloud governance can effectively reduce inefficient occurrences of cloud usage, therefore ensuring the responsible utilization of resources.

2) *Investing in Cloud Analytics:* Organization must have a method for determining the manner, the place and the people using its cloud services. This helps to ensure that the cloud services remain at its peak performance.

3) *Dynamic Uptime, Scaling and Scheduling:* Majority of the systems used in cloud platform comprises a large number of workstations, which functions only within the regular period for business activities on a daily basis. Back end systems are often times idle, other than running periodical batch functions. Therefore, systems should be analysed and organized by uptime needs such as 24/7 and weekdays only, as well as regular batch function. System can be scaled based on load or other metrics that are identified to ensure that they meet needs. System uptime should be automated based on categorization.

4) *Leveraging Purchase Commitments:* Major cloud service providers give out huge discount offers for reaching certain commitments over a period of time. Using the various spending models can reduce cost and increase return on investment. It is therefore necessary to identify uptime schedules to take advantage of an appropriate model.

5) *Lift and Shift Management:* Many cloud infrastructure start out as lift and shift projects, where existing on-premise infrastructure is mapped to the cloud on an as-is basis. This approach can result in oversized and inefficient system. Therefore, each system instance and feature should be sized according to true performance needs. Utilizing reserved instances and turning off unused instances have proven to be worthy steps in significantly reducing costs.

6) *Instance Sizing:* It is essential to choose one instance that matches an enterprises initial requirement. In the event that further usage and monitoring indicates the need to change the requirements, then adjustment of size can be made on demand.

7) *Auto Scale:* Using the cloud is embracing a dynamic environment that changes with demand. Auto scale is an important and basic cloud feature that allows cloud users to define their minimum and maximum instance pools as well as fundamental scaling metrics such as CPU utilization rate.

8) *Disposing Instance:* Unused capacity should be terminated based on predefined metrics and rules such as CPU utilization less than 10%. Using start/stop option for automatically capturing instances image and volume snapshots are helpful in performing recovery.

Reserved Capacity: Proper estimation of the planning and demand capacity can improve efficiency. Leveraging reserved and spot instances capacity also offer lower rates.

9) *Cheaper Storage and Compute Resources:* It is possible to have cheaper computer resources with spot instances or by deploying in a cheaper geographic region based on services availability. It is essential to transmit data from costly disk volumes to cloud storage. Using archive service like 'Glacier' can significantly decrease storage cost.

10) *Management and optimization Tools:* It is imperative to choose and implement devices that generate transparency and also helps an enterprise arrive at appropriate utilization of resources.

C. Optimization Architecture

In [3], a cloud optimization architecture is proposed. The proposed architecture is structured in layers. There are 3 optimization layers based on the 3 service models of cloud computing architecture, that is, the SaaS, PaaS and IaaS. In [3] is a figure that shows each layers' different optimization goals, sensors and actuators. Optimizing each layer represents the layers' interest to either maximise profit or increase user engagement and satisfaction. The methods of measuring optimization (sensors) or drive optimization (actuators) have been limited in type and number due to abstraction caused by virtualization and by SaaS concept.

1) *IaaS Owners*

a. Goals: the value of cost and revenue depends on the number of resources and price per resources. Ensuring cost reduction and revenue increment requires the full utilization of resources and maximising the resources by multiplexing. Recent reports have suggested that only about 10% of the entire IT resources are presently in use, it has also been proven hypothetically that resource utilization metrics can be improved up to a factor of 9. During actual process, only a factor of 5 – 7 is realistic. Service request initiated by the layer represents each VMs performance characteristics: memory, processing capability, and storage. Attaining optimal usage means that the management layer is required to ensure that the fewest number of hardware units are used to cater for all the requirements.

b. Constraint: Capacity constraints involving the IaaS owners include memory, storage, network and processors, which may change due to failures or equipment additions.

c. Sensors: The IaaS layer enjoys access to all hardware including the operating system and hypervisors. Sensors are tasked with measuring the usage capacity, the availability and location of each resource.

d. Actuators: The allocation of the VMs and storage represents the main actuators that satisfies the performance requirement and improve the layers' usage. In addition, activating or deactivating the VMs can increase usage without hampering the requirements output.

2) PaaS Owners

a. Goal. Revenue is realised from providing hosting services. Cost comprises the VMs resources, the amount of disk spaces used and the cost of using licences from third party companies, database services, and penalty it is incurs when SLA violation occurs. This layer's goal is to reach the maximum amount of applications hosted, and reducing the requirements needed and penalty it has to pay.
b. Constraint: SLA contracts with SaaS owner can be treated as hard constraints in place of cost. Delays in increasing the resources the CSP has can occur, and this may constrain these resources in the short term.
c. Sensors: The layer monitors its own VMs. The layer is restricted from accessing the hardware resources counter or virtualization hypervisors. The layer also has to monitor the resources of its collection of licences and a pay-per-use license of third-party software applications.
d. Actuators: This layer achieves its performance goals by acting on several handlers such as the type, number, size of VMs and also the allocation of containers to these VMs.

3) SaaS Owners

a. Goals: This layer is operation is centred on subscriptions. The cost of subscription is based on the revenue, which is dependent on the total amount of users and also dependent on the performance. Associated cost is comprised of payment for resources to PaaS, this cost also can be by subscription.
b. Constraints: Some SLA with applications could be treated as hard constraints.
c. Sensor: Each application maintains its optimal quality of service by ensuring it monitors the number of users over the amount of transactions. QoS includes response time for each user request and throughput of aggregated functions across multiple requests.
d. Actuators: Applications restrict the amount of requests it sends for resources from PaaS in order to reduce its cost. Applications should control the amount of instances, and deployment of the application.

D. Optimization Scenario

In cloud computing, optimization is a series of continuous activities, activated by deploying new applications, adjusting the workload characteristics, hardware crash and software components and maintenance activities.

a. Scene One: A burst of load for an application. The application must identify its requirement for extra capacity or better load balancing by streamlining its utilization in the new situation. Likewise, the PaaS layer must locate an optimal choice to provide it with resources it already possesses or request from the IaaS layer, which must be deployed and allocated additional VMs in an optimal manner.
b. Scene Two: The instant of a node failure rapidly reduces the availability of resources at all layers. The IaaS must identify the failure and act to replace the lost node by deploying new VMs and possibly copying the data at its current state. The PaaS layer may react then by deploying replica container in these VMs and finally, SaaS layer will deploy replica software.

E. Cloud Load Balancing

Cloud load balancing (CLB) is an essential process for management and optimization on the cloud. This comprises activities such as the distribution of jobs to be done and the distribution of resources required for processing. CLB gives companies the ability to accurately manage applications by sharing resources between several services or clients.

IV CLOUD COMPUTING IN AFRICA

The emergence and adoption of cloud computing is still in its early stage in most African countries. This section examines the adoption and use of cloud computing in four African countries. The selected countries represent each of the four regions, with Nigeria representing the West, Kenya representing the East, South Africa representing the South of Africa and Tunisia representing the North. South Africa currently has the highest activity in terms of cloud utilization, with demand arising from the private sector. It also possesses an indigenous cloud provider company, the Internet Solutions [18]. The other countries however have recorded certain level of highs and lows in the cloud computing sphere [18].

A. Cloud Adoption and Management in Nigeria

There exist several companies offering cloud services and solutions in the Nigerian market. A number of which include Amazon, Google, EMC, Cisco, HP, IBM, Microsoft, Sales Force and SAP [18]. The cloud computing industry in Nigeria is in early growth stages, much of its demands is on the IaaS. Mobile operators such Airtel, Glo and MTN have introduced several mobile cloud offerings targeted at the SME market [18]. Two American-based cloud providers, IBM and Sproxil have implemented solutions that enhanced the fight against drug counterfeiting. Consumers are able to ascertain the authenticity of drugs using mobile phones. By simply scratching off a code from a shiny seal on the pack of the drug and texting same to a designated number, consumers can verify if the particular drug is original and can also report the venue where the drug was purchased from, in cases where the drug is found not to be genuine. A survey conducted in 2011, predicts that by the year 2020, a large percentage of users will exchange information online, access software and interact with applications using only their smartphones, utilizing remote servers powered by cloud computing instead of having to install applications on their personal computers [20].

B. Cloud Adoption and Management in Kenya

Market competition and supply is emerging between local and international organizations in Kenya. Companies like Kenya Data Network (KDN), Safaricom Ltd and MTN are ahead in the delivery of the IaaS services [21]. Providers of PaaS services in Kenya offer services such as server provision, storage and backup systems, which is championed by the partnership between Safaricom and Seven Seas Company. The entry of this partnership into the cloud market has significantly changed the nature of events, by encouraging potentials users to explore local clouds as a workable alternative to foreign clouds [22]. [23] states the following as the obstacles facing cloud computing adoption in Kenya: security, infrastructure, internet coverage, lack of standardization, compliance and unavailability of hardware and software.

C. Cloud Adoption and Management in South Africa

Various companies are beginning to announce the benefits of cloud computing in South Africa. More companies have deployed some form of cloud computing in a bid to reduce operational costs [23]. Most recently, Google was rated as the most reliable cloud vendor in the country. Google cloud services include but not limited to, web hosting, application development, configuration and data backup, e-commerce, customer relationship management systems (CRM) and email hosting/archiving [24]. Estimations show that in 2013, South Africa had over twelve million cell phones connected to the internet [25]. This figure translates to meaning that every Internet connected mobile phone can access cloud services, ensuring availability and accessibility of the cloud services.

D. Cloud Adoption and Management in Tunisia

The increasing number of scientific conferences, workshops, business and technology events associated with cloud computing in Tunisia indicates the growing interest and awareness of the technology. These growing interests translates to increased investment possibilities [22]. Foreign companies such as Microsoft, HP and Oracle have shown rapid interest in the emergence of cloud technology in Tunisia. Universities have begun to encourage research in topic related to cloud computing [22].

V. ANALYSIS AND DISCUSSION

A. Cloud Optimization Strategies

Strategies for cloud optimization has over time gathered some reasonable amount of attention from cloud researchers. Presented in Table 1 are the works of different core authors concerning cloud optimization strategies. [26] highlighted two divisions of cloud optimization strategies. The divisions were based on the most used network resource in a particular cloud computing environment. These divisions are computing intensive and data intensive resources. Scheduling strategy for computing intensive tasks involves moving data to the high-performance computer and for tasks that are data intensive. The scheduling strategy should reduce the flow of data movement and hence decreasing its required transmission time. In [27], the author highlighted that the strategy for allocation of resources is a vital condition in cloud computing, as it ensures optimal use of scarce resources. In addition, the strategy for allocation of resources should be dependent on application characteristics, hence the need to avoid providing more resources than is necessary and preventing low usage of the provided resources and the service level agreements. [28] mentioned that a time-based optimization strategy would employ a more direct and aggressive dynamic provisioning utilization in a bid to reduce time required for execution. In [31] the authors stated that the resource allocation strategy should be responsive to changes in resource management policies and current network traffic situation. In this short analysis, only 33% of this core authors discussed issues relating cloud optimization strategies.

B. Cloud Virtualization

Virtualization constitutes a unique aspect of cloud management and optimization. An emerging interesting field of study, virtualisation-as-a-Service was highlighted in [33]. It was concluded by defining virtualization as the activity of substituting a physical resource with virtual (logical) resources, thereby reducing the amount of space required to store the resources. [34] mentioned that virtualization provides the platform and possibility for shareable and available-on-demand infrastructure. [28] opined that virtualisation enables the abstraction of computer resources thus enabling a single physical machine serve as multiple virtual machines. [30] contributed by stating that the current available virtualization technology and methodology offers the possibility to perform live migration i.e. migrating one virtual machine from one host to another without hampering its functions. Despite these contributions, only 25% of the core papers examined discussed the issue of cloud virtualization.

TABLE I
COMPARATIVE ANALYSIS OF CORE CLOUD MANAGEMENT OPTIMIZATION AREAS

References	Optimization Strategies	Optimization Architecture	Cloud Virtualization
L. Guo, et al. (2012)	x		
T. Nadu and V. P. Anuradha, (2014).	x	x	
R. Buyya, et al. (2011).	x	x	x
N. M. Calcavecchia, et al. (2012).			x
A. A. M., et al. (2011).	x		
B. Simmons, et al. (2010).		x	
M. Litoiu, et al. (2010).		x	x
V. R. Roopali Goel. 2012.		x	
L. Luo, et al. (2012).		x	
M. Paul and G. Sanyal. (2011).		x	
V. Nallur, et al. (2009).		x	
L. Y. Xiao, et al. (2013).		x	

C. *Cloud Architecture*

There exist several challenges to ensuring cloud optimization and hence the need for an architecture tackle such challenges [35]. The proposed architecture provides support for self-maintenance using automation of the tasks involved in the different stages of cloud optimization: monitoring, analysis and prediction, planning and execution. [32] presented an extension of the three-layered cloud computing architecture using strategy-trees. Each layer of the cloud architecture act as a manager representing the perspective of the provider, and utilising strategy-trees to implement feedback loops to attain desired objectives over a set period of time. It is not surprising that 75% of the papers reviewed focus extensively on optimization architecture because of its importance in management optimization.

VI. CONCLUSION

Cloud computing is evolving both in terms of technology and utilization. Cloud computing provides applications and also allow users deploy their own applications. Huge infrastructure is available to provide compute resource and storage for cloud users. Management and optimization is critical if cloud providers and users are to obtain maximum satisfaction from cloud activities. There are strategies for cloud management and optimization including technology tools and processes.

ACKNOWLEDGMENTS

We acknowledge the support and sponsorship provided by Covenant University through the Centre for Research, Innovation and Discovery (CUCRID).

REFERENCES

[1] P. Mell, T. Grance, “The NIST Definition of Cloud Computing”, NIST Special Publication 800-145, 2011.
[2] ‘Definition of Cloud Management’, Retrieved from: www.webopedia.com/term/c/cloud_management.html
[3] M. Litoiu, J. Ng, G. Iszlai, “A Business-Driven Cloud Optimization Architecture”, SAC’10, March 22-26, 2010, Sierre, Switzerland. ACM 978-1-60558-638-0/10/03.
[4] B. Addis, D. Ardagna and B. Panicucci, L. Zhang, “Autonomic Management of Cloud Service Centers with Availability Guarantees”, IEEE International Conference on Cloud Computing, 2010. DOI 10.1109/CLOUD.2010.19.
[5] J. L. Lucas-Simarro, R. Moreno-Vozmediano, R. S. Montero and I. M. Llorente. “Cost optimization of virtual infrastructures in dynamic multi-cloud scenarios”, Concurrency and Computation: Practice and Experience Concurrency Computat.: Pract. Exper. Published Online in Wiley Online Library (Wileyonlinelibrary.Com), 2012. Doi: 10.1002/Cpe.2972
[6] A. Beloglazov and R. Buyya. “Energy Efficient Resource Management in Virtualized Cloud Data Centers”, 10th IEEE/ACM International Conference on Cluster, Cloud and Grid Computing, 2010. DOI 10.1109/CCGRID.2010.46.
[7] S. Khatua, A. Ghosh, N Mukherjee, “Application Centric Cloud Management”, Access on 24 May 2016
[8] [8] A. J. Younge, G. V. Laszewski, L. Wang, S. Lopez-Alarcon, W. Carithers, “Efficient Resource Management for Cloud Computing Environments”.
[9] T. Pueschel, D. Neumann. “Management of Cloud Infastructures: Policy-Based Revenue Optimization”, ICIS 2009 Proceedings. Paper 178.
[10] R. Moreno-Vozmediano, R. S. Montero, and I. M. Llorente, “IaaS Cloud Architecture: From Virtualized Datacenters to Federated Cloud Infrastructures”, Published by the IEEE Computer Society, 2012.
[11] A. Singh, D. Juneja, M. Malhotra, “A novel agent based autonomous and service composition framework for cost optimization of resource provisioning in cloud computing”, Journal of King Saud University – Computer and Information Sciences, 19–28, 2017.
[12] N. Brender[1], I. Markov, “Risk perception and risk management in cloud computing: Results from a case study of Swiss companies”, International Journal of Information Management, 726-733, 2013.
[13] P. Nawrocki, W. Reszelewski, “Resource usage optimization in Mobile Cloud Computing”, Computer Communications. pp 1-12, 2017
[14] T. Püschela, G. Schryenb, D. Hristovab, D. Neumanna, “Revenue management for Cloud computing providers: Decision models for service admission control under non-probabilistic uncertainty”, European Journal of Operational Research, 637 – 647, 2015.
[15] M. Rouse. ‘Cloud Load Balancing’, TechTarget, ComputerWorld Publication, 2015
[16] D. Lucky ‘Cloud optimization: 3 Ways to improve the efficiency of your cloud usage’, Datapipe Publication, 2015.
[17] Equinix ‘Hybrid Cloud Optimization’, Retrieved from: www.equinix.com, 2016
[18] F. Odufuwa. Nigerian cloud report (unpublished), 2013.
[19] M. MILLER, Cloud Computing: Web-Based Applications that Change the way you work and collaborate online US: Que Publishing, 2009.
[20] K. JACKSON, D. PHILPOTT, "GovCloud: Cloud Computing for the Business of Government," Florida: Government Training Inc., 2011.
[21] M. Mureithi, Kenya cloud economy: The state of play of a nascent market (unpublished), 2013.
[22] Gillwald and Mpho, “The Cloud over Africa: Research ICT Africa,” 2012.
[23] R. K. Grewal and K. P. Pushpendra, "A Rule-based Approach for Effective Resource Provisioning in Hybrid Cloud Environment," International Journal of Computer Science and Informatics, vol. 1, no. 4, pp. 2231 - 5292, 2012.
[24] C. Hinde and J.-P. Van Belle, "Cloud Computing in South African SMMEs: Risks and Rewards for Playing at Altitude," International Journal of Computer Science and Electrical Engineering, vol. 1, no. 1, pp. 1 - 10, 2012.
[25] M. Grobler and Z. Dlamini, "Global Cyber Trends a South African Reality," in IST-Africa, Durban, South Africa, 19 - 21 May 2010.
[26] L. Guo, S. Zhao, S. Shen, and C. Jiang, “Task scheduling optimization in cloud computing based on heuristic Algorithm,” J. Networks, vol. 7, no. 3, pp. 547–553, 2012.
[27] T. Nadu and V. P. Anuradha, “Computing,” no. 978, 2014.
[28] R. Buyya, S. K. Garg, and R. N. Calheiros, “SLA-oriented resource provisioning for cloud computing: Challenges, architecture, and solutions,” Proc. - 2011 Int. Conf. Cloud Serv. Comput. CSC 2011, no. Figure 1, pp. 1–10, 2011.
[29] N. M. Calcavecchia, O. Biran, E. Hadad, and Y. Moatti, “VM placement strategies for cloud scenarios,” Proc. - 2012 IEEE 5th Int. Conf. Cloud Comput. CLOUD 2012, pp. 852–859, 2012.
[30] A. A. M., P. K., and W. a., “A framework for resource allocation strategies in cloud computing environment,” Proc. - Int. Comput. Softw. Appl. Conf., pp. 261–266, 2011.
[31] B. Simmons, M. Litoiu, D. Ionescu, and G. Iszlai, “Towards a cloud optimization architecture using strategy-trees,” Proc. 9th Int. Inf. Telecommun. Technol. Symp. (I2TS 2010), pp. 13–15, 2010.
[32] M. Litoiu, M. Woodside, J. Wong, J. Ng, and G. Iszlai, “A business driven cloud optimization architecture,” Proc. 2010 ACM Symp. Appl. Comput. - SAC ’10, no. May 2014, p. 380, 2010.
[33] V. R. Roopali Goel, “Cloud Computing and Service Oriented Architecture,” Int. J. Recent Technol. Eng., vol. 1, no. 1, p. 3, 2012.
[34] L. Luo, W. Wu, D. Di, and F. Zhang, “A resource scheduling algorithm of cloud computing based on energy efficient optimization methods,” IEEE Green Comput. Conf., vol. (2012) Jun, no. July 2007, pp. 1–6, 2012.
[35] M. Paul and G. Sanyal, “Survey and analysis of optimal scheduling strategies in cloud environment,” *2011 World Congr. Inf. Commun. Technol.*, pp. 789–792, 2011.
[36] V. Nallur, R. Bahsoon, and X. Yao, “Self-Optimizing Architecture for Ensuring Quality Attributes in the Cloud.pdf,” pp. 281–284, 2009.
[37] L. Y. Xiao, Z. Wang, R. Wang, and H. N. Wang, “Architecture and Key Technologies of Cloud Computing,” *Adv. Mater. Res.*, vol. 756–759, no. 200802860031, pp. 1953–1956, 2013.